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## ROLE OF THE AERODYNAMICIST IN A CONCURRENT MULTI-DISCIPLINARY DESIGN PROCESS

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### ABSTRACT

As the affordability of new aircraft and missile systems becomes an essential element of new development programs, the time spent in the early design (conceptual and preliminary design) needs to be reduced. This paper will address the time and activities associated with the conceptual and preliminary design of an aircraft, the role of the aerodynamicist in this early design period and the tools that he uses. The question of how the design time can be shortened will be discussed and what the aerodynamicist can do about it.

### INTRODUCTION

The Skunk Works has adhered to the motto "Quick, Quiet, Quality" in the development of many new and unique aircraft for over fifty years (Figure 1). The "Quality" was because the customer deserved (and demanded) it. The "Quiet" was because many of the Skunk Works programs were (and still are) "Black". The "Quick" was because "Time Is Money" and the faster a new product could be brought to the market, the less it cost. With the current world-wide emphasis on low cost and affordability, Quick is an essential new program parameter.

The design and development of a new aircraft (or missile) is naturally a serial set of tasks. Ideally, things should be done in order so that nothing has to be done over as new information becomes available. A notional serial schedule (to first flight) for developing an aircraft (excluding avionics and propulsion) is shown in Figure 2 (green depicts the conceptual design phase, yellow the preliminary design phase and the blue is the detail design). Unfortunately, this leads to a very long schedule and an expensive product. For Figure 2 it is 42-54 months from the start of conceptual design to first flight (with no problems that would stretch out the schedule). It is faster and cheaper if tasks can be done in parallel provided a serious design flaw doesn't precipitate scrapping a long and expensive task (ie; tooling and fabrication of parts). Typically, aircraft schedules are driven by the development of the VMS (vehicle management system, flight control), the engine (if it is a new engine) or delivery of the landing gear (simply because there are so few landing gear suppliers and they are very busy).

The Skunk Works has been relatively successful in shortening the time between contract award for a new design (usually the end of conceptual design) and first flight as shown on Figure 3. The two aircraft, A-12 and YF-22, that contradict this trend have reasonable explanations. The original schedule for the Mach 3+ A-12 was 20 months to first flight. The program turned out to be a tremendous technical challenge for the

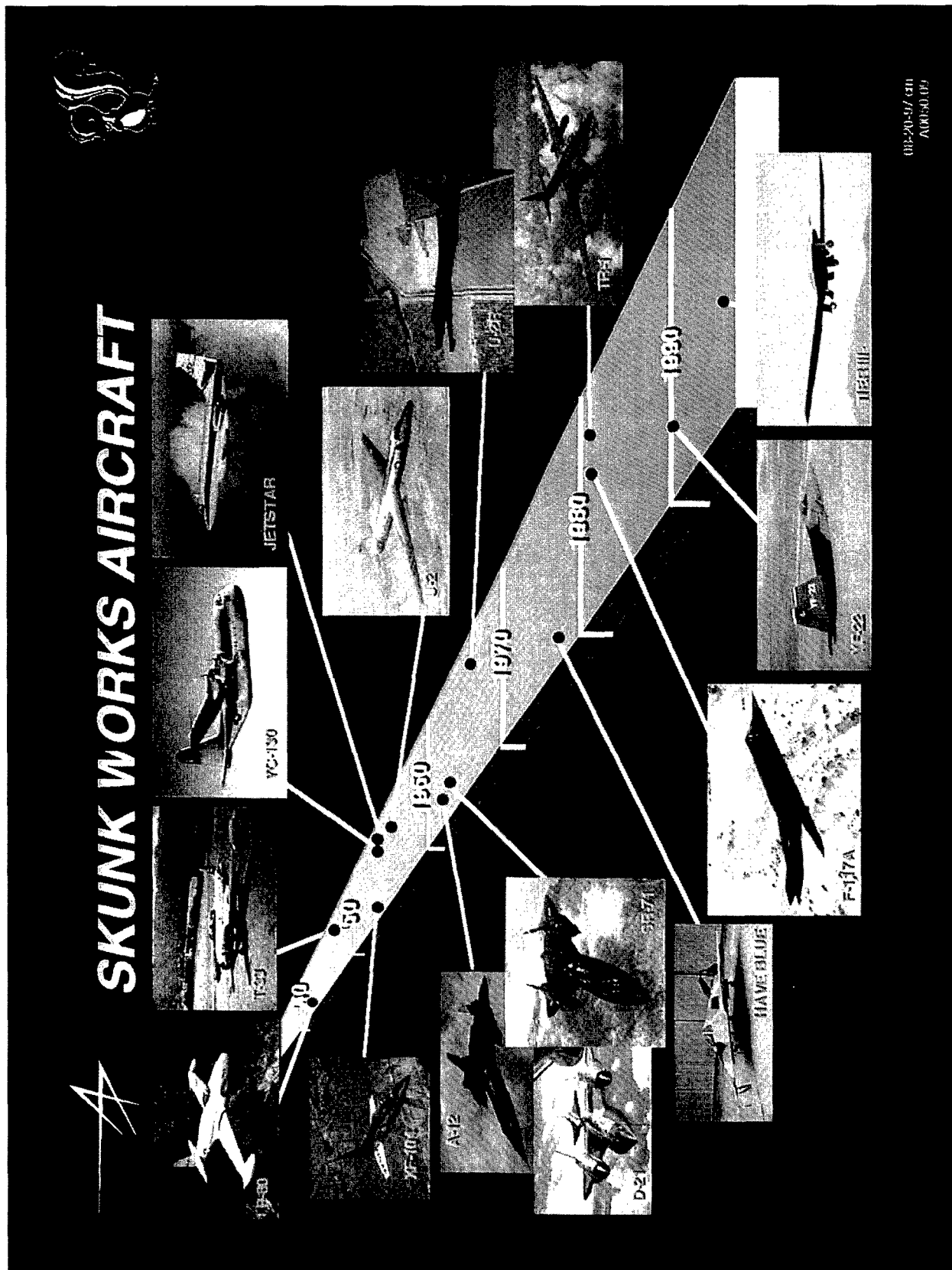
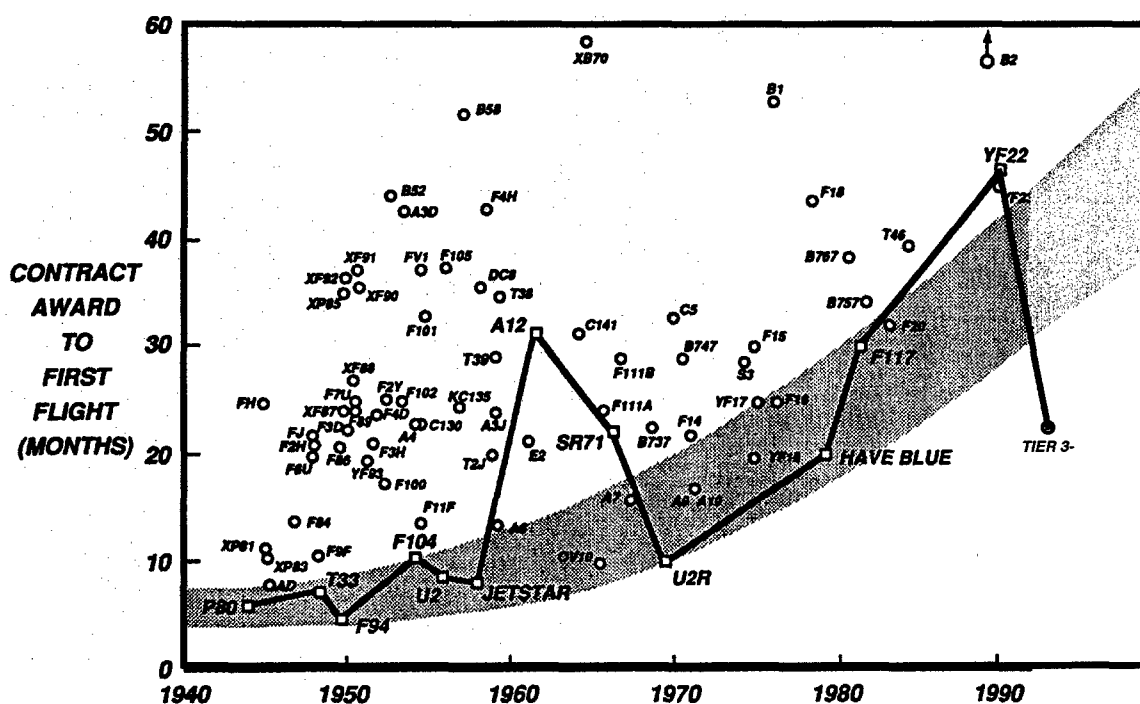


Figure 1. 50 Years of Skunk Works Aircraft

Skunk Works in the early 1960s (mixed compression inlet with translating spike, 85% titanium due to 600 °F surface temperature, fuels and lubricants operating at 350 °F, and the J 58 engine) and the program first flight slipped 10 months. Eight months after the dem/val contract award (October 1986) for the YF-22, the Lockheed team scrapped their prototype configuration and started over leading to the current configuration OML freeze in May 1988 and first flight in September 1990.

The Skunk Works success in reducing the time to first flight has been due partly to a close association and trust between LMSW and their customers leading to minimal specs, reviews and documentation. Also, being a quiet or black program helps shorten the schedule by keeping out the “lookie-loos”. But most of the reduced time has come from parallel tasking (concurrent development) and encouragement to use off-the-shelf (OTS) equipment, either Mil-Spec or commercial. Having an experienced, enthusiastic and “workaholic staff of engineers, designers and manufacturing people always helps also.



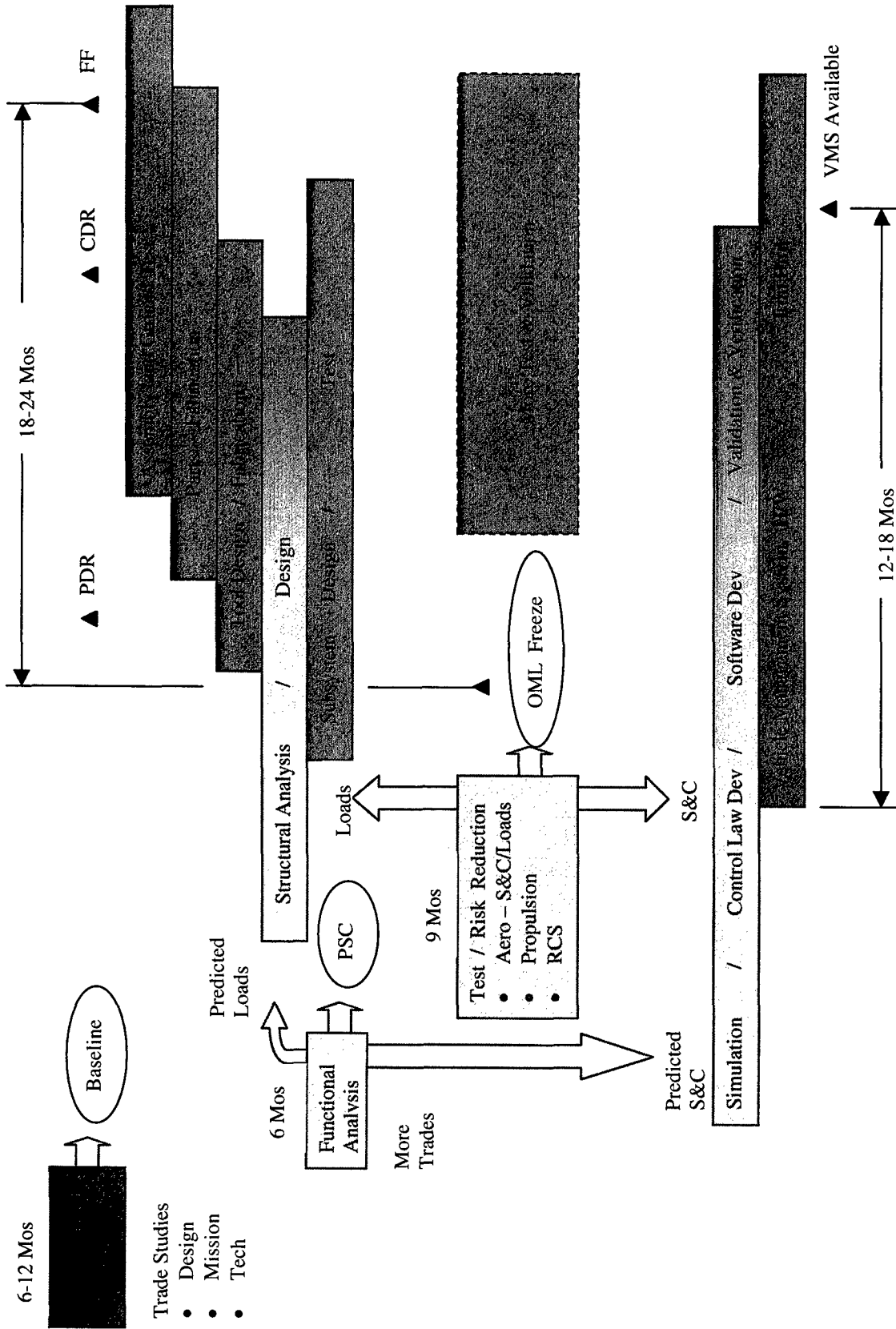


Figure 2 Serial Aircraft Development

It should be noted that the times shown on Figure 2 represents about half of the development time for a new aircraft. After first flight there is 3-4 years of developmental flight test (contractor clear- the-envelope testing, operational test and evaluation, etc.). In the past, the normal development program for a new aircraft was typically 8-10 years. With the emphasis on reducing cost, the industry is doing more concurrent development to reduce the total development time. The Skunk Works F-117 took 5 years to IOC (Initial Operational Capability) and the JASSM (Joint Air-to-Surface Standoff Missile) will take 76 months.

### **PARALLEL TASKING (CONCURRENT DEVELOPMENT)**

Parallel tasking or concurrent development means overlapping the task blocks shown in Figure 2 as much as possible. This is always dangerous as decisions are made many times during the program before having a complete set of data or based upon predictions. For example:

1. The outer mold line (OML) is frozen before aerodynamics, propulsion and RCS testing is completed.
2. Structural loads are estimated before the wind tunnel testing is completed so that the structural design can proceed earlier.
3. Flight control laws are developed before the wind tunnel testing is completed so that the flight control software and hardware development can proceed earlier.

The risk associated with this parallel tasking depends upon the complexity of the design and the maturity of the functional analysis codes (ie; CFD and CEM). The U-2A flew in 8 months because the design was simple, subsonic and stable and the structural design was started very early based upon predicted loads. The loads were verified later and found to be very close to the predicted loads (lucky or good?).

The risks associated with parallel tasking are mitigated by the formation of a vehicle IPT (Integrated Product Team). The vehicle IPT meets weekly with all personnel involved in the development of the vehicle. The people represented on the IPT include the functional engineering plus manufacturing, RMS, avionics, flight test and cost. These meetings address and resolve downstream issues before they lead to a conflict and impact schedule. The old practice of one group completing its task and throwing the results over the wall to the next group inevitably lead to sub-optimization and conflicts.

The use of OTS equipment (either Mil-spec or commercial) will usually lead to a form/fit penalty for the design but will greatly reduce the risk of a schedule slip. It is a good policy to demand that any new equipment item "buy" its way onto the vehicle by showing that OTS equipment will not work. The F-117A used the flight control computer from the F-16A, cockpit displays from the F-18A, landing gear from the F-15 and brakes from the Gulfstream II.

### **ROLE OF THE AERODYNAMICIST IN THE DESIGN PROCESS**

The aerodynamics group is at the center of activity during conceptual and early preliminary design because they "own" the OML (outer mold line) through their control of the configuration aerodynamic characteristics and performance. In conceptual design they define the initial configuration sketches and size the vehicles for the design group. Using their sizing tool they perform the design trades (wing loading, aspect ratio, sweep, thrust-to-weight, etc) and mission trades (range, payload, speed, etc). The design trades quickly reduce the design space and the mission trades answer the "what if" questions for the customer. The aero group is not working in a vacuum during this period because all disciplines are involved through the IPT process. The aero group, with help from propulsion, flight controls and RCS, develop the configuration OML for a baseline design.

During preliminary design the aero group leads the vehicle IPT towards the PSC (preferred system concept) by conducting configuration trade studies using a vehicle synthesis (sizing) tool. They then predict the configuration S&C characteristics for the flight controls group and verify the data base with

high fidelity wind tunnel tests. The aero group also works with the loads group to predict vehicle loads and verify the loads data base with high fidelity wind tunnel tests. Once these two important data sets are generated the center of activity shifts to designing and building the vehicle and integrating (stuffing) the subsystems (propulsion, flight control, ECS, etc) into the vehicle. The aero group continues to refine the PSC aerodynamics and performance.

Looking once again at Figure 2, it is quite clear that if aero doesn't do their assignment the whole schedule slides to the right. If aero misses on their wind tunnel test and has to modify the model and re-enter the wind tunnel, structural design and flight control law development slips. The responsibility of the aero group is to get it right the first time and shorten the design process. All engineering functions, but especially aero, must sharpen their analysis tools to consider multi-disciplinary issues. These tools must be user friendly and rapid turnaround.

## **RAPID CONCEPTUAL DESIGN (RCD)**

LMSW uses a program called Rapid Conceptual Design or RCD to shorten the time spent in conceptual design, potentially reducing the cycle time in half. This software tool is used by the aerodynamics group to perform the multidisciplinary trades and optimization studies leading to the baseline design.

The implementation of RCD with its distributed modeling and analysis software package reduces the time to perform the multidisciplinary trades and optimization studies in three ways. First, the passage of data from one tool to another is automated (historically this has been done off-line and has been a major consumer of time). Secondly, the output from one analysis that is input for another analysis is scheduled automatically within the program and passed between modules as required. Finally, the RCD software automates system trades by enabling automated multivariable parametric studies and optimizations to be conducted (providing rapid resizing of the design when individual parameters in standalone disciplines are changed).

Conducting a multidisciplinary trade study by conventional methods is a time consuming process dominated by the reformatting, transforming, and translating of data between design disciplines and analysis modules. In order to conduct trade studies and evaluate a design, data must be passed from one of these analysis tools to another. Efficient design analysis and optimization requires data handling and initiation of appropriate analysis codes independent of interactive user input. The resulting design architecture can yield significant improvements in turnaround times as well as a substantial reduction of non-value added tasks performed.

The effective evaluation of a design at the conceptual level requires the integration of multiple disciplines. Currently there are many conceptual analysis tools from all the major disciplines utilized in the design process. Throughout the design process the output of one analysis is repeatedly used as input for a subsequent analysis. Multidisciplinary design software can facilitate this process by providing scheduling of the analysis codes and communication between the codes. Also, different classes of vehicles require the use of different analysis codes. Analysis tools do exist which combine portions of major disciplines into a single working environment in order to eliminate the need for translation of data. The primary drawback of these historically complex and aging codes is that they apply to a predetermined set of design problems and are difficult to expand, modify and maintain.

The objective of RCD was to develop a design tool to facilitate multidisciplinary design analysis and optimization at the conceptual level, and that would have the flexibility to address non-traditional design problems. Traditionally, vehicle design optimization is a chain of sub-optimizations of single disciplines (two-dimensional gradient or hill climbing). Trade studies are conducted on individual components or subsystems (i.e. wing, engine, fuel system, hydraulic system, etc) using an analysis code tailored for the particular item. The results of the trade are then passed to the other design disciplines, which in turn analyze the impact of the trade on their area of responsibility. If the affected disciplines approve of the trade, their components or subsystems are modified and the change distributed to the

remaining design disciplines for evaluation. This two-dimensional process of change and evaluation is repeated until the design is closed. Unfortunately, this path along local optimums can very often miss a global optimum solution.

Multidisciplinary design problems are by their very nature, extremely interconnected and nonlinear. Therefore, in searching for an optimum solution, one cannot simply assume that a given solution is optimal in the global sense simply because the solution may be optimal locally. The problem then becomes one of not simply 'climbing the hill' but rather, first finding the hill that is the tallest, and then climbing. The methods employed to solve this type of problem must therefore have the ability to either avoid local minimums all together or escape them once they are encountered in order to be effective. This fact alone puts traditional gradient based methods at a disadvantage, as the optimum solution which they locate is dependant largely upon the point in the function space at which they started. Non-gradient based methods such as genetic algorithms, for instance, are better suited to addressing the problem of locating a global optimum, but typically do not converge to a solution as effectively as gradient based methods. Ideally, a non- gradient based method would be used to determine which is the tallest hill, and a gradient based method to climb it. This 'hybrid' optimization strategy allows gradient and non -gradient methods to be employed in a complimentary fashion in order to most efficiently address the problem. The relative strengths of these methods are exploited while their respective weaknesses are neglected, thus yielding the analytical benefits of both. Future growth plans for RCD include the implementation of this capability.

The flexibility of RCD to address non-traditional design questions was incorporated by developing a framework that would allow the integration of existing analysis and optimization codes in a modular format in which the designer could choose appropriate analysis tools based on the level of fidelity required and type of problem the designer is facing. The user could then decide which data should be sent from one tool to the next in order to provide an efficient environment for performing the multidisciplinary optimization. Once this data is linked it is sent between analysis tools automatically thus allowing the designer to focus on the design problem. The Rapid Conceptual Design process as illustrated in Figure 4 is based upon the premise that all the systemic variables of the system should be available and monitored from a central location or framework. The analysis tools supplying these variables however, should be free to run on any platform independent of the controlling framework.

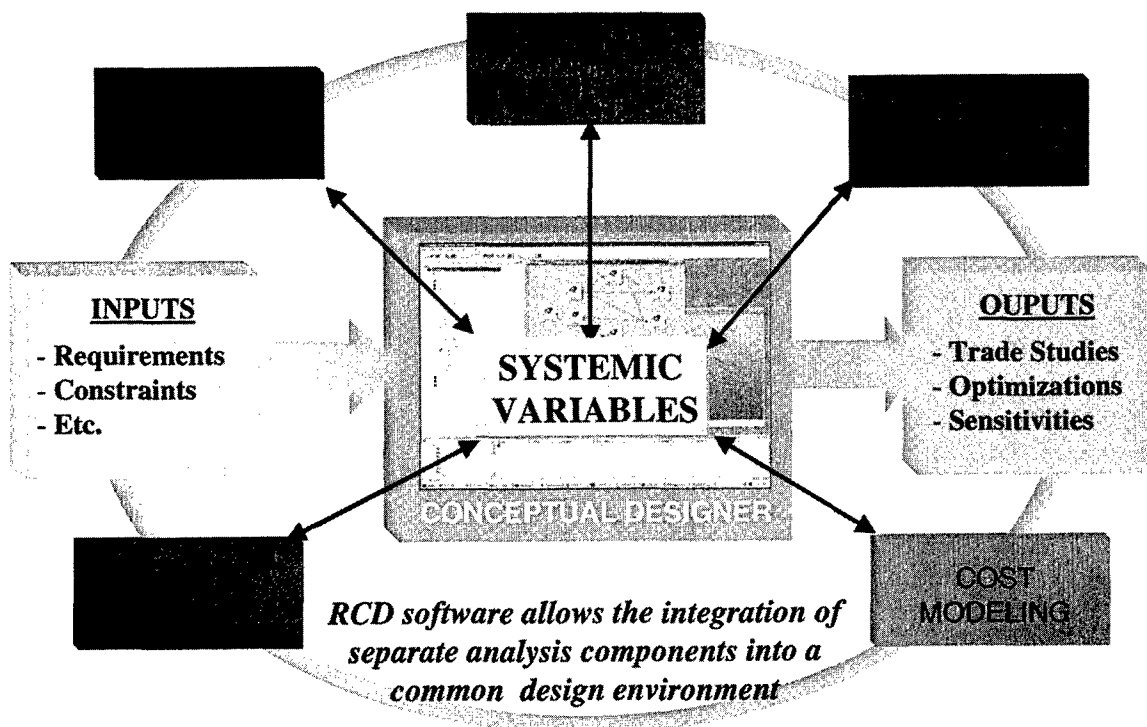


Figure 4 The RCD Process



## **RCD Case Study**

The RCD program was recently used on a very unique problem where the solution vehicle bordered on the fringes of the classical design space. Due to the unique nature of the problem, the sensitivity of the design to operational methods / modes and systems design options was not initially well understood. The lack of known design drivers coupled with the limited duration of the study (only 48 days) meant that development of the vehicle by standard design methods could result in a sub optimal configuration. The customer had indicated that a solution to the problem existed and that the current effort would be competing with the existing solution on a cost basis. Therefore a design that met the technical requirements would not ensure a contract win. Optimization of the design would be required to increase the odds of a contract award. The only way to accomplish an integrated vehicle optimization effort in the time allotted was to employ Rapid Conceptual Design (RCD) techniques.

As previously mentioned, the proposed vehicle would be competing against an existing solution on a cost basis; as a result the primary design goal was to produce a minimum cost vehicle. For aerospace vehicles weight (i.e. size) is usually the primary cost driver. Thus the goal for the sizing code would be to minimize weight. If the proposed vehicle could be shown to outperform the existing solution on a cost basis, the next phase would most likely be a fixed price development program. Since cost is strongly related to size, the sensitivity of the solution vehicle's size to changes in subsystem performance and material weight and strength properties needed to be well understood. Without this data appropriate margins could not be added to cost model.

The uniqueness of this particular vehicle design made it difficult to determine many of the initial design values. Having linked sizing modules and a sizing routine, which allowed time-efficient closed vehicle parametric trades greatly de-emphasized the need for accurate initial design values. The final system model is a testament to the above statements. It consisted of 23 analysis modules, 87 inputs, passed 122 design values between the individual sizing modules, and had 107 output design values. Sixty three of the 87 model input parameters were varied during the course of the design study to determine the sensitivity of the design to individual input values. The final 20, two dimensional, 5 x 5 design point parametric runs were conducted in a 20 hour period whereas using conventional methods these trades would have taken weeks to run. The end result of the final 20 parametric trades was a vehicle whose size was reduced by 33%. One of the parametric trades revealed that the current design philosophy was 180 degrees out of phase with the actual physical phenomenon. The customer and the design team, at that time, believed that relaxing a particular constraint would have a positive effect on the vehicle. In actuality the vehicle size decreased as the constraint was tightened. Another parametric trade addressed the distribution of a design requirement between two different systems that were tasked to satisfy that requirement. The optimal distribution from a standalone system analysis (based on the incorrect belief described in the above parametric trade discussion) was to have one of the two systems satisfy 100% of the requirement. The final parametric trade of these systems revealed that the optimal solution was indeed a distributed share of the duty. These two parametric trades together were responsible for 28% of the 33% weight reduction. This illustrates the true power of multidisciplinary design optimization: The identification of counterintuitive solutions with optimums that can only be identified through multidisciplinary design.

Automated data transfers greatly reduced the time required to complete vehicle aerodynamic build-ups. Automated parametric trade studies significantly reduced the time to perform parametric analysis. RCD models linking standalone analysis tools also reduced the time required to evaluate the effects of a system parameter change at the vehicle level by an order of magnitude. Finally, complete integration of the multidisciplinary trades and optimization through the application of the RCD methodology has enabled the identification of optimal solutions that are counter intuitive and functions of multiple design disciplines.

## **The Rapid Conceptual Design Methodology**

A required step in the RCD process is the creation of an 'integrated system model'. The system model should be capable of sizing the vehicle when given the design constraints. There are several steps to

creating the integrated system model. First the type of system which can best perform the mission must be determined from the design requirements. Next candidate configurations, systems architectures, subsystems, materials, etc. must be identified. For each candidate system the design input and output parameters must be identified.

Sizing modules, which determine the output design parameters given the input design parameters, must be selected or created. These sizing modules must then be integrated (i.e. the modules must be tied together such that the required information is passed between modules). Finally, a sizing closure module must be created to compile final design values and check for constraint compliance and design closure.

After the system model has been developed and verified, the optimization function (i.e. what constitutes the optimal vehicle) must be defined. The optimization function is usually a weighted function of the highest priority design parameters (range, speed, cost, etc.). Once the optimization function is defined, the optimum vehicle can be determined by varying the independent sub-system design inputs. The sensitivity of the optimal design to the design constraints can then be studied by performing parametric trades on each of the design constraints.

The next step in the RCD implementation process was to define a comprehensive list of disciplines and the information required from each discipline to design and develop an aircraft at the conceptual level. A sample minimum set of disciplines for an aircraft design trade study are: aerodynamics, propulsion, weights, thermodynamics, performance, stability and control and cost. Analysis tools capable of providing the minimum functionality in each discipline were assembled and integrated. With the basic library of analysis tools completed, verification cases and new design studies were conducted to evaluate the utility of implementing the RCD methodology in the conceptual design phases with the use of the distributed modeling and analysis tools.

Ideally, RCD software also provides an efficient user environment for the assembly and storage of individual analysis components into an integrated tool for the purpose of subsequent multidisciplinary design. These features will typically be tailored to the preferences of the user in order to extract maximum utility from the tool itself and subsequently ensure continued use of the code. The framework modularity allows the suite of available tools to be expanded to include future analysis tools. In addition, platform independent integration software allows analysis modules to be simultaneously coordinated on multiple computing hardware platforms.

## **STEREOLITHOGRAPHY (SLA) MODELS**

In the past, wind tunnel testing of vehicle shapes was reserved for the preliminary design phase because of the time and expense involved. Typical high fidelity models for low speed wind tunnel testing cost several hundred thousands of dollars and took 3-4 months to fabricate. This cost and time was not appropriate for the conceptual design phase.

During this decade a model making process has been developed which has drastically reduced the cost and time of fabricating high fidelity, low speed wind tunnel models. This process, called stereolithography or SLA, consists of using a UV-curable epoxy resin and an ultraviolet laser to create plastic models from a 3-D file. In this process, the CAD (computer automated drawing) part file is converted to cross-sectional layers, or "slices" of the part .006 inches thick. Using the laser, the SLA machine draws a layer of the part onto the resin, curing a thin cross-section of the part being built. The part is then lowered .006 inches, and recoated with resin. The laser then draws the next layer, which attaches to the previous layer. In this way a part is "grown" layer by layer.

The SLA parts do not have the strength required for large high speed wind tunnel models but do very well for small (approximately 10 percent) and low speed (less than Mach 0.25) model testing. With the SLA process small, high fidelity, low speed models can be built for less than \$10K and two weeks from

the time the NC tape of the loft is provided to the SLA operator. This cost and time fits within the conceptual design phase and competes with CFD for doing configuration trades.

The stereolithography process can be used for making parts for things other than wind tunnel models. At LMSW, SLA is used for making display models, RCS models, lay-up molds, patterns for molds, burnout patterns for investment casting, jig drill plates and welding jigs and example parts for proposals.

### **ADVANCED SYSTEM SYNTHESIS AND EVALUATION TECHNIQUE (ASSET)**

The RCD methodology is extremely effective when employed during conceptual aircraft design as several concepts are simultaneously considered, analyzed and pertinent trade studies conducted in order to explore the design space. During conceptual and early preliminary design, the aero group at LMSW uses a higher fidelity analysis tool called ASSET (Advanced System Synthesis and Evaluation Technique) to provide the detail necessary for more focussed trade studies.

ASSET is an analytical design program and data integration tool which analyses the vehicle configuration, weight, and cost through mission and performance analysis. It is a comprehensive data integrating system and analysis tool consisting of contributions from all of the technical disciplines during the early phases of aircraft design. It combines data from configuration design, propulsion, mass properties (structures, materials and weights), aerodynamics, subsystems, cost, and program requirements. All of these disciplines contribute data based on the design concept, customer requirements, and a technology level.

The main function of ASSET is to size (dimensions and weight) the aircraft to meet design criteria. A measure of merit such as the lowest cost, or the lowest weight is the most often used design criteria. To accomplish aircraft sizing, ASSET evaluates the impact of requirements imposed on the design by mission profiles and performance constraints. Parametric studies, where vehicle design parameters are varied, are used to determine impact of constraints across a range of designs. Sample parameters are the thrust-to-weight ratio to represent power plant size, and wing loading to represent airframe size. ASSET can vary these parameters and others to create performance, weight, cost and mission data for comparison purposes. These parameters are often plotted on carpet plots, which show the valid, invalid, and critical regions of the design space. Using these parametric methods, ASSET can rapidly evaluate alternate configurations during the design process.

It should be noted at this point that ASSET is not simply a 'back of the envelope' calculation procedure to quickly generate airplane performance parameters and weights. ASSET requires input from technical disciplines and large amounts of propulsion, aerodynamics, and weight data are required. This often requires time and personnel to acquire data and includes cooperation by several departments (e.g. acquiring engine performance tables or wind tunnel data).

One of ASSET's main features is its geometry routine which will grow or shrink (subject to realistic constraints of crew station, engines, weapons, etc) the configuration to accommodate a change in wing area, engine size, payload or fuel required. Design rules are entered to accomplish the dimension changes. Too often sizing programs will determine the increase in fuel required but not adjust the configuration dimensions to accommodate the fuel. ASSET does not mislead the engineer with this fault.

Lockheed Martin began incorporating ASSET's analysis routine with the NASA Ames Aircraft Synthesis Tool (or ACSYNT) in 1993, forming the ASCENT program. The main menu of ASCENT provides a selection for most disciplines involved with aircraft design. Selecting most of these options will allow the user to edit the portion of the ASSET input file used by these disciplines. Another feature of ACSYNT is its parametric geometry modification capability, accessed by the user in a 3-D parametric aircraft conceptual modeler. Employing this feature of the ASCENT program, the taper ratio and aspect ratio, for example, may be changed by altering values on the GEOMETRY template. When these parameters are changed, the entire B-spline surface definition of the vehicle is modified automatically.

Once the geometry is defined, aerodynamic analysis can be performed. A Lockheed-developed extension to ACSYNT allowed the parametric geometry to be analyzed by VORLAX, DATCOM, and WAVEDRAG II. The program then processes the output of these aerodynamic analyses and passes it on to ASSET for synthesis evaluation.

### AERODYNAMIC PREDICTION CODES

LMSW uses a stable of CFD codes to predict the S&C characteristics, drag and loads during conceptual and preliminary design. These codes are:

Name	Code Type	Grid Type	Application	Full Config Setup Time
VORLAX	Potential Flow	Vortex Lattice	Conc Design, S&C, Prelim Loads	<1 hour
Quadpan	Potential Flow	3D Panel	Conc Design, S&C, Aero Flowfield	4-8 hours
Splitflow	Euler	Intern Gen Hybrid Cartesian Prismatic	Aero/Prop Flowfield	4-8 hours
COBALT (Wright Labs)	Euler/Navier Stokes	Unstructured Polyhedral	Prelim Design Prop Integration	1 week
USM3D (LaRC)	Euler/Navier Stokes	Unstructured Tetrahedral	Aero Flowfield Analysis, Loads	1-4 weeks
Penguin	Parabolized NS	Structured Hexahedral	High Mach Aero/Prop Flowfield Analysis	1-4 weeks
ENS3D	Euler/Navier Stokes	Structured Hexahedral	Prelim Design, Aero/Prop Flowfield Analysis	1-4 weeks

The first three codes have full configuration setup times less than 8 hours and run times of minutes (VORLAX and Quadpan) to hours (Splitflow) and are used extensively during conceptual design to evaluate different configurations. The remaining CFD codes have setup and run times that limit their application to the fine tuning of baseline designs. In addition to the above CFD codes, LMSW has a complete stable of CEM (computational electromagnetic) codes for RCS predictions.

### SUMMARY

The aerodynamicist is at the center of the early design of an aircraft or missile as he "owns" the configuration OML through his control of the aerodynamics data base and performance. The aerodynamicist must have tools to predict the aerodynamics, S&C, performance and loads that are accurate and rapid turn-around. With these tools the aerodynamicist can reduce the time spent in early design (conceptual design to OML freeze).

## DISCUSSION

### Keynote Session, Paper #4

**Dr Khalid (NRC, Canada)** offered thoughts on need for both structured and unstructured codes as each was suited to particular types of problem that were likely to be encountered in initial design.

**Dr Nicolai** concurred.

**Mr Woodford (DERA, UK)** wondered whether aerodynamicists were in fact the people best qualified to drive the overall design of an air vehicle, for example given likely pressures to ensure an affordable design.

**Dr Nicolai** sought to confirm that he had not intended his comments to apply to the overall vehicle design, but merely to its outer mold line (OML). He did not believe that OML was a first order cost driver.

**Herr Sacher (DASA, Germany)** wondered whether the design team's interactions described in the paper would still work if the teaming were "virtual".

**Dr Nicolai** suggested that, whereas the interactions probably would work if the teaming were virtual, his preference was still for collocation, given the importance of direct personal contact.

**Mr Templin (NRC, Canada)** requested amplification of the author's assertion that "the aerodynamicists own the OML", citing as an example the F-117 where the shape was clearly constrained by other disciplines.

**Dr Nicolai** accepted that aerodynamicists might very well have constraints, sometimes significant constraints, imposed on them but, nevertheless, they are the group that has to ensure that the vehicle will "fly". He was adamant that whatever these constraints might be, this responsibility determined that no-one was able to modify the OML without aerodynamics approval.

**Prof Straznicky (Carleton University, Canada)** wondered how much interaction there was between aerodynamics and the other disciplines in the early conceptual design phase.

**Dr Nicolai** replied that the interaction described took place through normal operation of the IPT. He noted that this met at least weekly. He further noted that ideally all disciplines should be colocated "so that there is no excuse for not getting together daily".